Cash for Tests: Investigating Water Quality Monitoring Constraints

A Proposal to the Water, Sanitation & Hygiene Program Bill & Melinda Gates Foundation

Cover Photo: Addressing constraints to water quality testing. The Office National de l'eau Potable (ONEP) of Morocco is a public organization responsible for national drinking water supply management. To cope with limited personnel capacity for rural water quality monitoring, ONEP supports independent, private 'water testing micro-entrepreneurs' who conduct onsite chlorine assays and collect samples for microbiological analysis at regional laboratories.

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improving health through clean water innovation

I. Charitable Purpose

To improve the public health outcomes of water, sanitation and hygiene programs in sub-Saharan Africa by developing evidence-based strategies for efficient, accurate and systematic microbial water quality testing.

II. Executive Summary

Contaminated drinking water is a primary exposure route for fecal pathogens, and microbial water quality can provide an objective public health indicator for WaSH programs. Currently, however, reliable and comprehensive water quality information from developing countries is limited.

On the surface, this dearth of microbial water quality data is surprising: globally, drinking water provision is a highly regulated activity that includes requirements for water quality monitoring. National regulatory agencies generally base their monitoring standards on guidelines established by the World Heath Organization (WHO), which emphasize the health risks associated with microbial contamination. Despite this prioritization, microbial water quality testing rarely achieves regulatory requirements for frequency and coverage in developing countries.

Why doesn't microbial water quality testing meet regulatory requirements? Commonly cited constraints include the challenging technical, logistical, and financial requirements for both diagnosing microbial water quality and managing water quality data. We propose an 'action research' program to document the actual extent of these constraints in sub-Saharan Africa (SSA): we will attempt to motivate increased testing by urban water suppliers and public health surveillance agencies, particularly in neglected and low-income areas, through a combination of incentives, capacity-building grants, and cost-based payments for completed tests.

Participants who are able to meet increased testing goals in response to a first study round of simple financial incentives for completed tests will identify institutional contexts where the primary testing constraints are likely to be motivational. In order to engage with additional institutions that suffer from real capacity constraints, we will conduct a second study round that includes capacity building grants and cost-based payments for tests. Institutions that fail to meet testing targets in this second round will identify technological (for example, a lack of appropriate field kits), procurement (for example, an absence of equipment and supply distributors), and managerial (for example, inefficient fund transfers to laboratory and field staff) constraints.

Our objective in documenting the actual constraints to microbial water testing is to inform strategies for achieving optimal levels of testing that can guide both local water management and broader WaSH sector public health efforts. By evaluating constraints in collaboration with a range of institutions, we will assess needs and requirements for the multiple factors that influence microbial water testing: appropriate diagnostic technologies, regulations, resource allocations, technical capacity, laboratory infrastructure, and management practices.

III. Project Description

Who's responsible for collecting microbial water quality data?

Globally, drinking water provision is a highly regulated activity with specified requirements for water quality monitoring. Developing countries generally base their water quality monitoring standards on guidelines established by the WHO.

In order to ensure the delivery of safe drinking water to consumers, the WHO *Guidelines for drinking-water quality, 3rd edition* (2004) recommends two complementary monitoring activities: 1) operational monitoring (or water quality control) by water suppliers; and 2) surveillance (or compliance) monitoring by an independent agency (WHO 2004). Our research confirms that water quality standards or related sector policies in across a range of developing countries mandate these two monitoring activities and that they dominate water quality testing in practice (Rahman *et al.* 2011).

operational monitoring by water suppliers

Regular operational monitoring by water suppliers is considered a primary tool for maintaining process control and verifying water quality. Optimal operational monitoring triggers immediate corrective actions when test results indicate that a water supply system is compromised because a necessary process is out of its efficient operating range or because final water quality does not meet requirements. Operational monitoring should be carried out frequently, at the local level, and is often limited to a set of critical parameters such as pH, residual chlorine, turbidity, coliform bacteria, and observable factors related to system integrity (WHO 2004, Lloyd & Bartram 1991)

surveillance monitoring by health authorities

Surveillance monitoring requires an agency, usually responsible for public health and independent from water suppliers, to assess the compliance of all drinking water supplies, including unimproved and untreated sources, with national standards (WHO 2004). This independent monitoring function insures against potential reporting biases that might arise during operational monitoring by water suppliers. Unlike operational monitoring, surveillance monitoring can be infrequent but should include a comprehensive evaluation of the adequacy of supplies, including quality, quantity, accessibility, affordability, and continuity (Lloyd *et al.* 1987, Lloyd & Bartram 1991, WHO 2004). Drinking water surveillance is ideally linked to resource allocation, planning for improvement of water supply systems, and oversight of suppliers.

What are the constraints?

The WHO guidelines emphasize the health risks associated with microbial contamination and our analysis of the policies and institutions that govern water quality management in nine developing countries confirms that microbial water quality monitoring is broadly recognized as a public health priority and mandated by national regulations (WHO 2004, Rahman *et al.* 2011). Despite this emphasis, our current collaborations with water providers and public health surveillance agencies in ten countries across Africa, Asia and South America suggest that testing activity only achieves required levels at water treatment plants in large urban centers (See Appendix 1 for a summary of our collaborators).

Why doesn't microbial water quality testing meet regulatory requirements? Factors that might prevent institutions from meeting national standards for microbial water testing fall into at least four categories (Box 1); capacity, procurement, motivational and programmatic constraints.

Regulatory testing mandates the use of accredited diagnostic assays that are performed by trained personnel in licensed laboratories. There are also a few field test kits (i.e. the Del Agua membrane filtration kit and the Hach Potatest) that have gained regulatory acceptance in some settings. Unaccredited assays, such as the H_2S test, are also available. A number of **capacity** and **procurement** constraints are commonly associated with these methods:

- laboratories are limited and poorly maintained
- trained personnel are scarce, unmotivated, and underpaid
- testing reagents and lab supplies

Capacity Constraints
- Facilities
- Equipment
- Budget for consumables
- Trained personnel (testers and managers)
- Resources for transport

Procurement Constraints
- Limited access to distributors of testing equipment, supplies and consumables
- Inability to manage or control purchasing

Motivational Constraints
- Lack of performance incentives for testing personnel
- Poor enforcement of testing standards
- Recognition that distribution networks are corrupted and that water is invariably contaminated

Programmatic Constraints
- Limited use of water quality data, poor information management
- Limited jurisdiction over informal settlements

Box 1: Constraints to Water Quality Testing. Capacity, procurement, motivational and programmatic constraints prevent institutions from meeting national standards for water quality testing.

are unavailable
- sample transport from rural areas to laboratories is impractical
- field kits are too expensive
- field kits are difficult to use in the field
- field kits are rarely resupplied with reagents
- unaccredited assays are unreliable and not accepted by authorities

In addition, **motivational** and **management** factors may hinder water quality testing:

- water quality managers may not perceive value in frequent microbial water quality testing; for example, some managers may assume that chlorine levels are the primary indicators of microbial water safety, or managers may recognize that distribution networks are corrupted and that water is invariably contaminated
- poor enforcement of water quality testing standards
- water quality managers may attempt to hide system inadequacies by limiting testing
- in larger cities, jurisdiction over informal settlements and accompanying responsibilities for water provision and management is often unclear

Test payments for evaluating constraints

In recognition of the technical challenges to microbial water quality testing in developing countries, the Foundation has supported the Aquatest program at the University of Bristol, UK, with the primary objective of developing a low-cost, simple-to-use diagnostic that will provide reliable, quantitative measurements of microbial water quality, in the absence of laboratory facilities and highly trained staff (Rahman *et al. 2010*). We propose to build upon this effort by documenting all constraints to testing: capacity, procurement, motivational and programmatic. We will study constraints by trying to motivate increased testing by urban water suppliers and public health surveillance agencies in selected SSA cities with a combination of incentive payments, capital investment grants, and cost-based payments for completed tests. Participants who succeed in meeting testing targets will identify institutional constraints that can be alleviated with increased incentives and funding; failures will identify barriers to testing that extend beyond financial constraints.

Setting the scope

We propose to focus on urban centers in SSA that include a representation of large primary cities and smaller secondary cities. These two urban settings provide distinct contexts for water testing activities.

primary cities

Utilities will have their own facilities for operational testing. Surveillance agencies may rely more heavily on "audit-based" surveillance: monitoring of test results supplied by water suppliers with occasional independent verification through direct testing.

secondary cities and towns

Utilities are likely to send water samples to private accredited laboratories or public health laboratories for operational testing, and surveillance is likely to be direct testing by local public health agencies.

Implementing test payment schemes in various urban settings will allow us to study the constraints associated with multiple operational and surveillance testing models.

We will select target countries according to criteria that include the following elements:

- strong institutional frameworks and/or progressive water sector policies and institutions
- alignment with the foundation's priorities
- political stability

Building on our experience in assessing water sector policies and institutional arrangements, we will establish a short-list of targeted countries during a research stage at the beginning of our program. We will finalize the list based on discussions with national sector authorities and potential program participants and according to responses to our Request for Proposals (RFPs) for program participation.

Establishing working sector relationships

Implementing our test payments program with a range of municipal water utilities and public heath surveillance agencies in SSA will require convening groups with sector authority to promote and support our research. Fortunately the following water utility convening groups are active in Africa:

- African Water Association (AfWA)
- International Water Association (IWA)
- Global Water Operators' Partnership Alliance (GWOPA) hosted by UN HABITAT

We will present our study and discuss sub-grantee options with each of these groups.

Similarly, engagement with public health surveillance agencies in multiple countries will require introductions and possible program facilitation by regional public health authorities. We will discuss sub-grantee options with WHO and UNICEF officials.

For additional expert input to our research methods, development of RFPs, contracting procedures with program participants, and data analysis we propose to collaborate with Professor David Levine, Trefethen Professor of Business Administration, Hass School of Business, University of California, Berkeley.

IV. Alignment with Foundation Strategy

Foundation interests

The Foundation's Water, Sanitation & Hygiene program is dedicated to improving public health in developing countries by reducing the fecal-oral transmission of diarrheal disease pathogens through the development of safe, effective, and affordable sanitation services. Microbial water quality is an important indicator for the program's (and other WaSH sector) efforts. In addition, comprehensive monitoring is essential for targeting interventions and assessing their outcomes and sustainability throughout the developing world.

Background research: water quality monitoring

institutional roles

This project builds on our research on institutional frameworks and capacities for microbial water quality testing (Rahman *et al.* 2011). We have reported on the relative clarity of institutional responsibilities for operational monitoring by formal urban suppliers and for surveillance monitoring by the health sector. However, we observed that among water suppliers, capacity for operational monitoring varies greatly. We also found that although institutional responsibility for water quality surveillance lies with the health sector in most countries and is generally linked to a broader public health framework, in some poorer countries, such as Cambodia and Malawi, responsibility for surveillance monitoring has not been established; and even where institutional responsibility is well defined, surveillance agencies are commonly constrained by limited funding and human resources. As an example, the Figure provided in Appendix 2 compares the institutional framework for Ecuador, where the institutional framework is robust, with Malawi, where the institutional framework is relatively weak (Appendix 2).

Our findings align with a survey of thirty-eight water sector institutions conducted by M.C. Steynberg, which found that while most countries do have national drinking water standards, these are rarely enforced (Steynberg 2002). Steynberg concludes, *"An effective system that assess compliance to drinking water specifications and at the same time ensures the consumer safe and healthy water, therefore, does not exist for most consumers"* (Steynberg 2002). Lloyd and Helmer (1991) also determined that many surveillance agencies do not have the financial, human or logistical resources to support regular surveillance monitoring, especially in rural areas where water sources are widely dispersed. Similarly, a study from South East Asia found that while surveillance is more common in urban than rural areas, even urban surveillance is focused on piped supplies and rarely includes alternative sources (Howard & Bartram 2005).

While these studies document constraints to surveillance monitoring, there is limited information on methods to improve monitoring capacity. In one example, Howard and Bartram (2005) suggest that in order to maximize public health impact and prioritize water supply improvements in urban areas,

surveillance resources should be targeted to vulnerable areas, especially those without direct access to piped supplies. In Peru and Uganda, pilots of this targeted approach led to the inclusion of marginalized areas within surveillance programs and of interventions that improved alternative water sources commonly accessed by the poor: for example, in Peru the surveillance agency carried out a dedicated study on tanker trucks providing water in slums (Howard & Bartram 2005). Our test payments program will include the first comprehensive analysis of institutional roles for achieving optimal levels of microbial water quality testing in SSA.

performance monitoring

Although there are various efforts, such as the 2009 *Water Operators Partnerships Africa Utility Performance Assessment,* to measure municipal water utility performance in Africa, these evaluations tend to focus on service continuity, coverage and financial sustainability; they rarely report on end-of-pipe water quality or capacity for operational monitoring (Mugabi & Castro 2009). In rural market centers and small towns of SSA, water supply management is increasingly delegated to small-scale private operators, especially where supplies are too large for community management and too small for typical utility networks (Moriarty *et al.* 2002; Moriarty & Verdemato 2010; Gia & Fugelsnes 2010). Researchers suggest that increasing private sector participation in piped water service provision necessitates strengthening the government's regulatory role (Moriarty *et al.* 2002). Furthermore, indicators of operational performance, including water quality, are considered critical for managing contracts with private providers (Gia & Fugelsnes 2010). Our program will evaluate both current capacity for monitoring and water quality status among large water suppliers and inform the discussion on small-scale private operator regulation by exploring the feasibility of microbial testing for operational and surveillance testing in small towns.

Finally, our program coincides with recent international discussions on appropriate metrics for measuring access to safe drinking water. Recognizing that water supply type (i.e. improved vs. unimproved) is a poor proxy for water safety, the WHO/UNICEF Joint Monitoring Program has recently held a series of Task Force meetings to discuss options and strategies, including the use of national regulatory data, for generating comprehensive water quality data (WHO/UNICEF 2011). Our work will provide a practical assessment of the feasibility of improving regulatory monitoring in resource poor settings.

Financial incentive development models

Performance incentives, conditional cash transfers, output based aid (OBA), and cash on delivery (CoD) are all policy tools employed across a range of professional contexts that reward outcomes as a means to achieve sector goals. Our study design utilizes elements of both CoD and OBA interventions, which generally target institutions. OBA and CoD development models both reward measurable outcomes, however, they differ in the intention and nature of rewards: the CoD model assumes that inputs and activities are financed through other mechanisms and that the only relevant cost function for determining CoD payment amounts is that of empowering and motivating local actors (Hallet and Over 2010); in contrast, OBA payments are designed to subsidize full program costs (GPOBA 2011).

Our research design utilizes elements of both the CoD and OBA approaches. Round 1 is based on the CoD model: we offer incentive payments that only partially subsidize testing costs in order to identify institutions that largely suffer from motivational constraints to testing. Recognizing, however, that the majority of water suppliers and surveillance agencies in SSA also face substantial capacity constraints and that there is much to be learned from studying these institutions, we shift to an OBA approach in round 2. In the second round, we will offer per test payments intended to subsidize the marginal costs of testing. When necessary, we will also offer up-front grants for capital investments, as in a traditional aid model.

V. Sustainability and Scalability

Municipal water utilities and public health surveillance agencies that participate in our test payments research program will have the opportunity to build technical and personnel capacity for water quality monitoring. We anticipate that the multi-country scope of our program and our dissemination activities will also increase awareness around microbial water quality testing in sub-Saharan Africa and promote

regulatory oversight. Ideally, these program outcomes will promote sustained testing beyond our program period. Greater testing will catalyze competition among equipment and reagent suppliers that will reduce costs and encourage scaling-up.

However, we also recognize that a majority of the municipal water utilities and public health surveillance agencies that do not participate in our program will continue to face significant constraints to testing. In order to leverage the research outputs of this program, we will pursue all opportunities for developing sector-wide strategies for addressing the political, financial, and technical constraints that hinder microbial water quality testing in sub-Saharan Africa.

VI. Implementation, Intended Results, and Results Measurement

A. Results Framework

See separate file: Aquaya_CashforTests_ResultsFramework_10March12

B. Project Plan

A multi-round payments scheme for differentiating and evaluating constraints to testing

We propose an action research exercise that employs a multi-round payments scheme to identify and evaluate constraints to microbial water testing among water providers and public health surveillance agencies (Figure 1).

We begin with the assumption that water providers and surveillance agencies will fall into two broad classes:

1. Institutions in larger cities that have the capacity and procurement facilities to increase testing levels. Members of this class that do not meet national testing standards presumably suffer from motivational and management constraints.
2. Institutions in smaller cities and towns that are capacity constrained (they lack one or more of the following testing requirements: facilities, equipment, consumables and trained personnel). Most members of this class probably do not meet national testing standards. In addition to capacity constraints, they may also face motivational and management constraints.

In order to study testing constraints among a representative group of institutions in both classes, we propose a sequential approach:

1. *Round 1:* We will issue an RFP to participate in a CoD incentives payment program. We will offer a fixed incentive payment designed to partially subsidize on-going testing costs. Institutions that choose to participate (presumably those with existing capacity to increase their testing levels) will receive a payment for each microbial water test conducted in excess of their current (baseline) testing activity. Per test payments will be higher for tests completed in under-tested (particularly low-income) regions in their areas of responsibility.

   Participating institutions that meet their testing goals will likely represent organizations that primarily face motivational constraints: in the absence of incentives, meeting microbial water testing standards is not a high priority in these organizations.

   Participating institutions that do not meet their testing goals will identify organizations that contend with constraints that cannot be overcome with limited financial incentives. These may be capacity, procurement, management, and/or motivational constraints (Box 1).

2. *Round 2:* To engage institutions that chose not to participate in the CoD incentives payment program (presumably those with capacity, procurement, management, and/or motivational constraints that cannot be addressed with per-test incentive payments), we will offer planning grants to support the collaborative development of cost-based payment plans for meeting national testing standards. These cost-based plans may include both up-front capacity building payments and per-test payments.

We will also offer planning grants and collaborative development of cost-based payment plans to institutions that were enrolled in our CoD incentives payment program (Round 1) but failed to meet their testing targets.

We are not planning to randomly assign some Round 1 participants to Round 2, because our objective for Round 1 is to determine the prevalence of water providers and surveillance agencies with existing capacity and resources for achieving optimum testing levels. Moving some Round 1 participants directly to Round 2 before establishing their ability to meet testing targets with partial incentive payments will reduce our ability to assess the existing water testing potential within this class of program participants.

Among institutions that accept a planning grant, we may identify some with overwhelming capacity constraints that we cannot alleviate within this program. Among the remaining institutions that we choose to enroll in a cost-based payments program, those that meet their testing targets will identify successful strategies for overcoming capacity and procurement constraints. Those that do not meet their testing targets will identify organizations that were unable to overcome capacity and procurement constraints despite our funding.

Institutions that choose not to participate in a our collaborative needs assessment and cost-based payment program may identify organizations that are actually motivated not to increase their levels of microbial water testing: for example, their distribution networks may be in high levels of disrepair and likely to supply contaminated water.

We anticipate that achieving optimum levels of enrollment in Rounds 1 and 2 will require a significant recruitment effort to overcome the bureaucratic inertia that we've experienced in many public water sector institutions. We will tailor our recruitment program to try and ensure participant representation that fills all of the institutional classes that we've identified for our research (large city providers, medium city providers, small town providers and surveillance agencies) in all target countries. If, however, interest in our program is higher than we expect and any institutional classes are oversubscribed, we will randomly select final program participants.

How will we study testing constraints?

Our analysis of institutional constraints will comprise three main components:

1. We will document perceived constraints to meeting national testing standards through responses to our RFPs and through baseline surveys with institutions that choose to participate in our payments program and with those that choose not to participate.
2. In the second (cost-based payments) round of our payments program, we will conduct a collaborative needs assessment for increased testing with program participants. Working directly with organizations to document and evaluate their needs for increased water testing will provide a hands-on opportunity to learn how testing programs are prioritized and structured across a range of settings.
3. To identify mechanisms used to overcome constraints, we will combine analysis of actual financial expenditures for microbial water testing (a prerequisite to participating in our program) with surveys of program participants. Tracking financial expenditures will identify both successful and unsuccessful applications of financial inputs in testing programs.

Multi-Round Payments Scheme

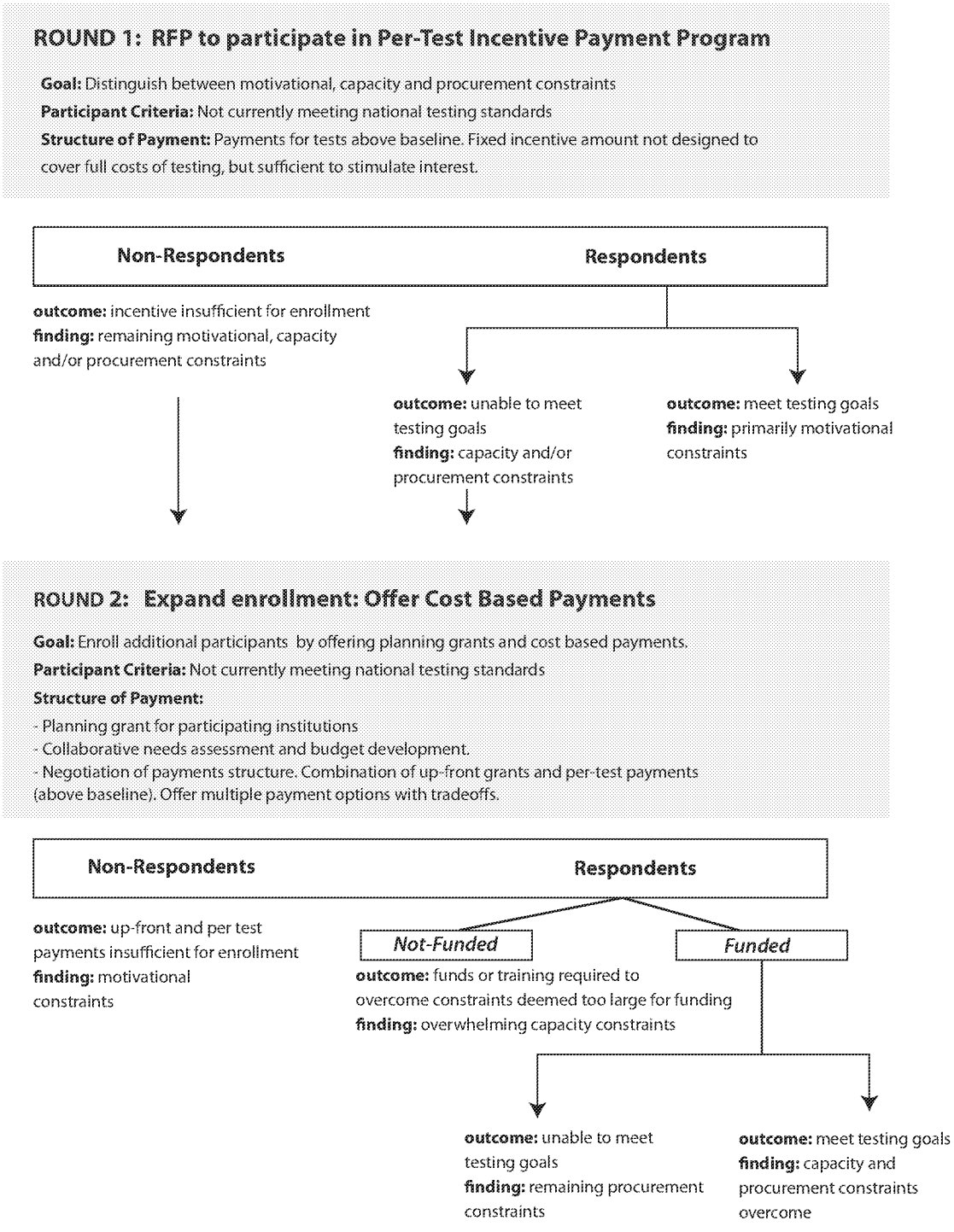

Figure 1: Multi-round Payment Schemes. We propose two rounds of payment programs (the first offering incentive payments and the second offering cost-based payments) to distinguish between the capacity, procurement, and motivational constraints faced by institutional microbial water testing programs in sub-Saharan Africa.

Major activities

The activities in our proposed multi-round payment schemes program are outlined in the Results Framework file and our Program Timeline (Appendix 3). Key activities are discussed in detail below.

relationship building and information gathering

Establishing interest in and support for our microbial water testing research exercise within the municipal water utility and public health sectors in SSA are fundamental requirements for our program that will require intermediation by credible sector convening agencies. Consequently, developing partnerships with organizations such as the AfWA, IWA, GWOPA, WHO and UNICEF are early program priorities.

We will also meet with national water sector administrators and regulators in target countries to introduce the program, solicit feedback and obtain official endorsements. The relationship-building phase will culminate with a workshop, organized in collaboration with our convening partners, which will include potential program participants (municipal water utilities and public health surveillance agencies), water sector authorities, and regulators. The workshop will not only serve to solidify sector 'buy-in' across the region but will also include our first phase of qualitative research, with discussions focusing on current constraints and perceptions of what kinds of rewards schemes and other inputs would be required to improve testing. We will incorporate feedback on constraints and priorities gathered from stakeholder consultations into our programmatic activities.

Round 1: per-test incentives payments

We will use an RFP to recruit candidates for our Round 1 CoD incentive payments program. We have three main goals for this first round:

1. Identify institutions that already possess the capacity and procurement facilities to readily ramp-up their testing levels.
2. Determine how these well-resourced institutions adjust their activities to increase testing levels.
3. Clarify why institutions were not meeting national testing standards prior to entering our program.

Applicants will be asked to describe their constraints to testing and provide strategies for addressing these constraints. We will market our RFP to institutions in all target categories (large, medium and small water utilities, and surveillance agencies) through our convening partner networks and memberships and through selected in-person visits. Our RFP will provide information on the goals of our research and on the details of the payments program. We will finalize the per-test incentive amount based on information on actual testing costs gathered during the relationship building and information gathering stage. We may elect to offer different incentive amounts for utilities and surveillance agencies if evidence from the relationship building and information gathering stage indicates that actual costs of testing are significantly different in these distinct institutional contexts.

The RFP will ask candidate institutions to propose a plan for improving monitoring and outline the activities and costs associated with achieving the plan. Proposal evaluations will focus on evidence of commitment to our per-test incentives payment program. Following participant selection, we will negotiate and finalize payment models, data-sharing strategies, and cash transfer mechanisms.

In order to promote maximum participation in Round 1, and in recognition of the potential appeal of capacity development grants, we will only announce the existence of Round 2 once we have identified Round 1 candidates and program agreements are under negotiation.

Contracts with all participants will establish the following parameters:

- outcomes to be rewarded
- outcome metrics
- reward amount(and if/how it will change)
- testing targets
- maximum payout
- cash transfer mechanisms
- information sharing requirements

Round 2: cost-based payments

In the second round, we will study testing constraints among institutions that chose not to respond to our Round 1 RFP (presumably because they did not view per-test incentive payments as sufficient motivation to increase testing levels) and among institutions that did not meet their testing targets in Round 1. We have two main goals for this second round:

1. Collaborate directly with organizations to identify and evaluate perceived needs for increased testing.
2. Determine if and how poorly resourced institutions increase their testing levels if their perceived needs are met.

As shown in our Program Timeline, institutions that chose not to participate in Round 1 will be targeted for Round 2a shortly after candidates are selected for round 1 (Appendix 3). After six months of program implementation, we will offer Round 1 candidates who have failed to increase testing an opportunity to engage in a needs assessment and to transition to cost-based payments (Round 2b).

We will provide all compelling Round 2 candidates with a small planning grant to collaborate with us in conducting a comprehensive assessment of their needs for increasing microbial water testing. Based on this needs assessment we will develop customized cost-based payment plans for each candidate. These plans may include an up-front payment for capital expenditures and per-test payments to cover operating costs.

Expenses associated with increased testing might include the purchase of test equipment and reagents, technical training, transportation, information management systems, and dedicated management time. Institutions without any existing laboratory facilities and trained staff (for example, many small town water utilities) may require some initial investment to increase testing. Up-front payments will allow these institutions with high 'start-up' costs to participate. In contrast, institutions with established sampling and testing programs may only require payments to support additional staff time and reagent purchases. Rather than providing the funds for these ongoing costs up-front, per-test payments will ensure that participants are rewarded only for achieving results. Based on our knowledge of the inputs required for monitoring, we will be able to distinguish between necessary and unnecessary inputs and identify grossly inflated budgets.

In order to encourage Round 2 candidates to rigorously analyze their needs, we will provide potential participants with a menu of payment options that, for example, ask participants to trade a higher up-front payment for lower per-test payments and a lower overall payment. Participant choices between these options will clarify the nature of their financial (especially cash flow) constraints. The monetary value of the up-front and per-test payments will vary for each program participant, based on their existing capacity and testing infrastructure and their proposal for addressing constraints.

In order to maximize our analysis of constraints, we will also ask candidate institutions to consider whether their improvement plan might change with an option for in-kind inputs. Although we do not plan to provide these in-kind inputs (at least initially), we can evaluate whether institutions would plan improvements differently if they were offered assistance with specifics such as procuring equipment or developing a monitoring plan. For example, an institution may propose sending samples at a high cost to an external laboratory if they do not feel confident in their technical capacity to conduct testing on-site. If offered technical assistance in on-site testing, their preferred option may change.

establishing testing targets

In both Rounds, our test payment schemes will reward two types of results:

1. Number of tests
2. Geographic prioritization of tests

We intend to offer participants a fixed payment each month for each test above the baseline. This represents a continuous, linear payment function in which payments are proportional to the scale of the outcome achieved (Hallet & Over 2010). To supplement this continuous payment, we will offer a bonus threshold payment when participants reach testing targets. Per-test payments will also stop once participants reach this threshold. In order to establish a baseline for each participant, we will audit water

quality testing records and calculate the average number of tests completed each month for the year prior to entry into our research program.

Per-test payments will be higher for tests in clearly specified 'priority areas' in order to promote monitoring in neglected or high-risk regions. Among water utilities, these priority areas will include low-income neighborhoods and sampling points at the ends of the distribution systems (where contamination is more likely). Among surveillance agencies, priority areas will also include low-income neighborhoods and regions rarely tested at baseline (presumably areas further from the large cities, these may overlap with low income areas). We will ensure that priority areas are defined and mapped so that water samples can be geo-referenced.

In order to support well balanced testing programs and to avoid introducing perverse incentives (i.e. institutions reallocating all resources to priority areas at the expense of other areas under their jurisdiction or drawing down on future budgets), we will place the following conditions on payments:

1. Given the importance of monitoring in the distribution system, we will set a limit for how many tests will be rewarded from raw water and the water treatment plants.
2. We will only provide higher payments for tests in priority areas up to an established maximum amount, beyond which per test payments will drop to match the amount for non-priority areas.
3. Payments will stop once numerical targets are achieved.

Table 1: Recommended minimum sample numbers for faecal indicator testing in distribution systems (adapted from Table 4.5 of the *WHO Drinking Water Guidelines Third Edition*).

Population	Total Samples per year
< 5,000	12
5,000 - 100,000	12 per 5,000 head of population
> 100,000 - 500,000	12 per 5,000 head of population plus an additional 120 samples
> 500,000	12 per 5,000 head of population plus an additional 180 samples

The *WHO Guidelines for Drinking-water Quality* recommend minimum sample numbers for microbial water quality testing in the distribution system for piped drinking water supplies as shown in Table 1 (WHO 2004). In addition to these distribution system samples, which verify 'end of tap' water quality, utilities should monitor raw water and water immediately after treatment.

We will establish numerical testing targets in collaboration with participating institutions according to national standards, which we expect will largely follow the WHO guidelines (see Appendix 4 for a list of the national standards that we have reviewed to date) (Rahman *et al.* 2011). Based on the WHO guidelines and our research on public health surveillance testing, we can predict approximate test numbers for a range of participant types (Table 2). We estimated testing targets for distribution systems based on WHO recommendations (Table 1). In addition we suggest that utilities conduct a daily test directly after treatment in the reservoir and a weekly raw water test.

Table 2: Estimated microbial test numbers. Targeted test numbers for a representative breakdown of program participant institutions in Kenya.

Institution Type	Example Location (population)	Tests per month			Total Tests in 16 months
		Distribution Network+	Reservoir and Raw Water*	Total	
1. Large city provider	Nairobi (3.2 mill)	655	34	689	11,024
2. Medium city provider	Nakuru (300,000)	70	34	104	1,664
3. Medium city	Thika (200,000)	50	34	84	1,344

provider					
4. Small town provider	Bondo (30,000)	6	34	40	640
5. Surveillance min.	Nyanza Province	60	--	60	960
6. Surveillance max.	Rift Valley Province	100	--	100	1,600
Total tests per country over 16 months					**17,232**
Total tests for five countries (30 institutions) over 16 months**					**81,160**
+ Based on WHO recommendations, see Table 1.					
* In addition to tests in the distribution network, we recommend one test a day at the treatment plant (reservoir) and a weekly test of raw water.					
**We assume a similar institutional breakdown in each country in order to predict total test numbers for 30 institutions across five countries.					

Accordingly, we estimate that approximately 81,160 tests will be conducted by 30 participating institutions across five countries during a 16 month implementation period.

In addition to targeting increased testing in priority areas, we will also require that large city providers provide public access to their water quality data. We will initiate data sharing activities with large city providers for two reasons:

1. *They are the most likely to have systems in place (websites, mailers, newspaper advertisements, etc…) for data sharing; and*
2. *They serve large urban populations that are relatively accessible and, potentially, more likely to demand and assess water quality information.*

predicting costs and structuring payments

Based on the institutional breakdown and the numerical testing targets presented in Table 2, we next estimate the fraction of total tests that we will reward through this program and the corresponding payments that we will make to each participant (Table 3). Although we have calculated preliminary numerical testing targets according to WHO recommendations, we expect significant socio-economic disparities in large and medium sized cities. Consequently, we will reward additional testing in marginalized areas (see 'Beyond Targets' in Table 3).

Based on our analysis of existing capacity for water quality testing and our goal of engaging institutions with a range of baseline activity, we predict that participating institutions will be conducting between 20% and 80% of target tests at baseline (Table 3). For example, we assume that a large city provider such as Nairobi City Water and Sewerage Company is already testing at 80% of targets. In contrast, a provider in a small town such as Bondo, Kenya probably relies on an external laboratory for infrequent testing and only achieves 20% of targets. Given these baseline assumptions, we expect that participating institutions will conduct approximately 34,948 tests above their current baseline level during the 16 month implementation period (Table 3).

Our program participants have the opportunity to receive up to four distinct payment types:

1. Per Test Payments (Round 1 & 2)
2. Planning Grants (Round 2 only)
3. Capital Investment Grants (Round 2 only)
4. Cash Bonuses (Round 1 & 2)

We currently estimate that per-test payments will begin at $20 (Round 1 CoD incentives) and reach up to $40 (Round 2 cost-based payments). We estimate capital investment grants to between $10,000 and

$15,000. In addition we will offer most program participants $2,000 bonuses for reaching testing targets and additional $2,000 planning/needs assessment grants in Round 2. *For the largest program participants (large city providers – up to five), we will raise the bonus payment to $5,000 to provide a more meaningful performance incentive for these large institutions.* Our per-test payment estimates are based on actual costs, provided by our current collaborators, of setting up laboratories and for conducting ongoing testing (Appendix 5). Based on these estimates, we predict that payments to thirty program participants will total approximately $1.3 million and that the average payment per institution will be $43,553 (Table 3). These figures assume that all 30 institutions will reach their numerical testing targets and, therefore, represent a maximum payment outlay.

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Table 3: Total tests, tests above baseline and payment amounts based on predicted range of participating institutions.

Institution Type	Target tests in 16 months	Baseline Assumption	Round	Tests to Target (16 months)	Beyond Targets (16 months)	Per Test Payment	Total Per Test Payments	Planning Grant	Capital Investment Grant	Cash Bonus	Total Payment
1. Large city provider	11,024	80% target	1	2,205	500	$20	$54,096			$5,000	$59,096
2. Medium city provider	1,664	50% target	1	832	200	$20	$20,640			$2,000	$22,640
3. Medium city provider	1,344	30% target	2	941	200	$30	$34,224	$2,000	$10,000	$2,000	$48,224
4. Small town provider	640	20% target	2	512	NA	$30	$15,360	$2,000	$15,000	$2,000	$34,360
5. Surveillance min.	960	50% target	2	480	NA	$40	$19,200	$2,000	$10,000	$2,000	$33,200
6. Surveillance max.	1,600	30% target	2	1,120	NA	$40	$44,800	$2,000	$10,000	$2,000	$58,800
				Total tests (1 country, 6 institutions)	18,132				Total payments (1 country, 6 institutions)		$256,320
				Total Tests (5 countries, 30 institutions)	**90,660**				**Total payments (5 countries, 30 institutions)**		**$1,281,600**
				Total Tests above baseline (5 countries, 30 institutions)	**34,948**					**Average payment per test**	**$36.67**
										Average payment per institution	**$42,720**

measuring results

We will reward participants for tests completed based on audits of water quality testing data. To facilitate daily data collection from multiple sites, we will rely on a combination of mobile phone-based data entry systems and web based reporting. We will utilize mobile phone-based systems with surveillance agencies because their staff tends to be decentralized and responsible for monitoring in remote regions. This approach leverages our experience in implementing the Water Quality Reporter mobile phone application with water providers in Vietnam and Cambodia and with public health surveillance officers in Mozambique. For this program we will also consider EpiSurveyor and Open Data Kit: popular and reputable open source tools that provide both phone applications for data submission and associated "back end" components for data aggregation and remote viewing. In the case of utilities, we plan to use web-based reporting forms because testing tends is conducted in centralized locations and utilities are generally equipped with computers and internet access.

We will evaluate incoming test data with reference to the targets and testing plans established for each participant. Payments will be made on a quarterly basis in order to provide participants with proximate feedback on their performance while minimizing transaction costs of transferring funds.

research methods

We will utilize quantitative data on testing (as described above) and qualitative data from participant surveys to evaluate the impact of our payment models, to identify factors that currently constrain microbial water quality testing, and, where applicable, to explore the mechanisms by which program participants increased testing. Baseline measurements and surveys with program participants will provide quantitative data on frequency and coverage of testing as well as qualitative data on current testing practices and perceived constraints. *To ensure that we obtain a complete analysis of perceived constraints our baseline research will include interviews with local sector experts from national water agencies, international development organizations and other stakeholder groups.*

In Round 2, we will augment our information on perceived testing constraints through collaborative needs assessments with program candidates. End-line surveys will identify changes in testing and water management activities and any ongoing constraints to increased testing. We will monitor testing frequency, coverage and microbial water quality on a daily basis for up to 16 months of program implementation.

In addition to conducting surveys with program participants, we will analyze records of financial expenditures to determine how participants used additional financial resources to address testing constraints.

data analysis

We expect program participants to fall along a continuum towards achieving testing targets, with some institutions meeting or exceeding targets and others making poor progress. This potential range of results, illustrated in Figure 2, allows us to ask a number of research questions. In cases where participants meet or exceed testing targets, we will ask the following questions:

- how was optimal testing achieved?
- what is the perceived value of initiating or increasing microbial testing?
- do data trigger corrective actions or influence operations?
- did perceptions of water supply safety change?
- where does appropriate testing material come from?
- where does knowledge and expertise come from?
- is increased testing correlated with improvements in water quality?

In cases where participants could not meet testing targets, we will ask the following questions:

- what were the barriers that could not be addressed through our payments program?
- what is required to overcome remaining barriers?
- do data from existing microbial testing inform water system management?

In answering these questions, we will develop a comprehensive understanding of the following issues related to microbial water quality testing:

- factors that constrain microbial water quality testing in SSA
- microbial water quality status across multiple regions of SSA
- whether increased testing is correlated with water quality improvements
- how water quality data are used to guide water management practices, including how data are perceived by institutions and how corrective actions, if any, are implemented.

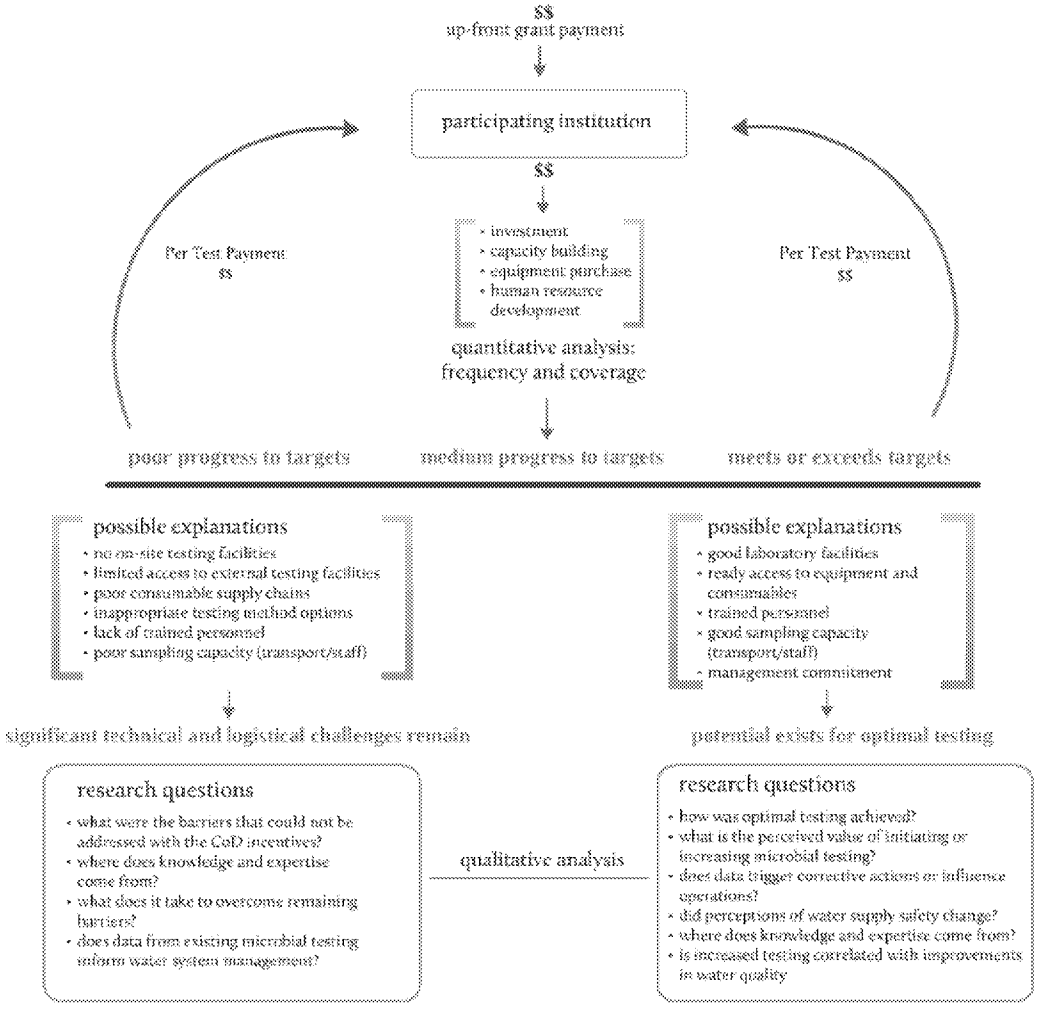

Figure 2: Potential results. A continuum of improved testing.

Additional considerations

learning from those that don't apply

We will also follow up with targeted institutions that choose not to participate in Rounds 1 and 2 of our payments scheme to understand their positions:

- Are these institutions averse to improving their testing programs (i.e do they suffer from significant motivational and management constraints)?
- Do they perceive that their testing constraints cannot be addressed through our program?
- Are they over-burdened with other programs?
- Do they face bureaucratic barriers to participation?

nuances of water quality surveillance by public health agencies

Our research on institutional frameworks for drinking water quality has identified two primary approaches to water quality surveillance by public health agencies: 1) direct testing by public health officials, and 2) audits of test data collected by water suppliers (Rahman *et al.* 2011). The audit-based approach is more common in urban centers where municipal utilities have the resources and capacity for operational monitoring. To design a payment model that conforms to the practices of local public health surveillance agencies, we will need to understand how they employ the direct and audit-based approaches. We may decide to focus on the public health agencies that do conduct direct testing, which will likely select for program participants that monitor smaller cities and towns or rural water supplies.

what happens when our payments stop?

As a condition to participation in our payments schemes, we will ask participants to provide us with access to their monitoring data for six months after the per-test payments are completed. Determining whether institutions continue testing or decide to stop with the end of the payments program will provide further insight into ongoing constraints and motivations. After our test payments program is terminated, one possibility is that Round 1 institutions that faced motivational constraints will return to baseline testing levels and that Round 2 institutions that received capacity building funds will continue testing above baseline, but may drop from 100% of targeted testing to approximately 80% (Table 4). In this scenario, an additional 8,040 tests above baseline will be completed each year following the program.

To foster continued testing after the completion of our payments program, we will communicate with national water regulatory and oversight agencies from the start of our program. Demand for increased water quality monitoring and data reporting by these agencies is an important requirement for sustaining higher testing levels. We predict that demand for monitoring data will rise as the WaSH sector starts to focus on post-2015 development goals, which are likely to emphasize improvements in water quality (WHO/UNICEF 2012). Low demand from national regulatory and oversight agencies for ongoing monitoring data will identify another constraint to microbial water quality testing in SSA. To promote our engagement with national sector agencies and encourage ongoing demand for monitoring data, we have identified 'maintained testing' after the completion of our payment program as a key outcome that includes a reward payment for excellent achievement (see section on 'Linking budgets and reward payments to program outcomes' below).

Table 4: Testing forecast for annual testing following close of payments program

Institution Type	Annual Target Tests	Annual Tests as Baseline	Percentage of Target Maintained	Annual Tests after Program	Maintained Increase over baseline
1. Large city provider	8268	6,614.4	80%	6,614.4	0
2. Medium city provider	1248	624	50%	624	0
3. Medium city provider	1008	302.4	80%	806.4	504
4. Small town provider	480	96	80%	384	288
5. Surveillance min.	720	360	80%	576	216
6. Surveillance max.	1200	360	80%	960	600
Annual tests above baseline (1 country, 6 institutions)					**1,608**
Annual tests above baseline (5 countries, 30 institutions)					**8,040**

Vision of success

Our goal is to develop evidence-based strategies for achieving optimal levels of microbial water quality testing across SSA. These strategies will inform testing requirements and practices, resource

management and allocation, capacity and infrastructure development, water test development and regulatory acceptance, and water test distribution and availability. We will disseminate our findings through a dedicated program workshop with program participants, national regulatory and oversight agencies, convening agency partners, the Foundation, and other relevant sector stakeholders. We will also present our findings at sector conferences and author reports and peer-reviewed publications.

The main objectives of our dissemination activities are two fold:

1. *to establish our strategies as recommended practice by influential sector convening and development agencies: for example, IWA, AfWA, WHO, and UNICEF*
2. *to incorporate our strategies into national sector policies*

To meet these objectives, we will include sector convening agencies as subgrantees in the program implementation. We have also planned for on-going meetings and discussions with national regulatory and oversight agencies. Specifically, we have built a dedicated six-month, 'policy engagement' activity into the program that will commence upon completion of our payments schemes.

To ensure that our program generates appropriate communication and dissemination materials, we will contract with a communications consultant for the creation of a program website and the design of program fact sheets and briefs. We will also produce 'Water Quality Training Modules', comprised of manuals and video. We will first use these training modules to refresh program participants on microbial water quality monitoring principals and on the use of microbial water quality data in water management decision making. Upon completion of our program, we will update these modules with research lessons and make them freely available as sector resources.

The promotion of 'Water Safety Plans' as risk-based water supply management tools represents a compelling model for a successful dissemination effort. Through focused regional training efforts accompanied by a dedicated conference series and a range of training and evaluation materials, WHO, IWA and other partners have successfully introduced Water Safety Plans as a management tool for larger utilities across Asia and Latin America. They are now increasing attention on uptake of Water Safety Plans in Africa. As an illustration of their success, the Asian Development Bank's Vietnam water team requires water utility loan applicants to develop and implement Water Safety Plans (pers. comm. Hubert Jenny, Principal Urban Development Specialist, Asian Development Bank).

Value for money

As a research effort, our primary program objective is to document and analyze constraints to microbial water testing, not to address all constraints and maximize testing. Nevertheless, our multi-round payment plan provides a cost-effective means for increasing microbial water quality testing, while simultaneously maximizing research outputs. By only providing an incentive payment, Round 1 leverages prior investments in infrastructure and personnel to push high-capacity institutions to reach testing targets. Payment plans for Round 2 will be developed through collaborative needs assessments and budget development. Funds in this round will directly support the capacity building necessary to reach testing goals. In addition, it is important to note that our program will provide a large-scale longitudinal analysis of microbial water quality across SSA.

Linking budgets and reward payments to program outcomes

We have identified six key program outcomes that will serve as milestones for evaluating and rewarding project success (See Aquaya_CashforTests_ResultsFramework_9March12):

1. *Demonstrated interest from convening organizations, sector agencies and potential participants (utilities and surveillance agencies) (**Month 9**)*
2. *An operational framework for implementing a water testing research program (**Month 12**)*
3. *Agreements with program participants in place for both rounds of our Cash for Tests payments scheme: round 1 = incentive payments; round 2 = cost-based payments (**Month 18**)*
4. *Water testing targets achieved by round 1 and round 2 program participants (**Month 30**)*
5. *Maintenance of testing after we stop payments (**Month 36**)*
6. *Policy impact: Strategies for scaling-up microbial water quality testing across sub-Saharan Africa (**Month 39**)*

Progress towards our first two program outcomes will determine the future direction of our program. If we have not established sufficient interest in our research strategy from potential program participants and national regulatory and oversight agencies by month 9, we will present options for revising our approach. This milestone coincides with the conclusion of our 'relationship building' phase, which culminates with a stakeholder workshop in month 9. Optimally, our Foundation Program Officer will attend this workshop to evaluate the response to our research methodology. Our ability to develop an operational framework, complete with program participants, by month 12 will serve as a 'Go/No-Go' milestone for continuing the program.

C. Analysis

Our project plan, budget, and timeline are based on our experience in conducting applied research in a number of developing countries and with a wide range of institutional partners in the water sector. Under the Aquatest Research Program, we have negotiated formal agreements for piloting microbial water testing systems with governmental and non-governmental organizations in over ten countries across Africa, Asia, and South America (Appendix 1). For this proposed test payments program, formal partnerships with sector convening agencies will greatly facilitate access to the African water sector, and we will dedicate time and effort to building these relationships. Similarly, consultations with governmental authorities, regulators and potential program participants will ensure that our payment models are aligned with sector realities and that we are able to recruit appropriate program participants.

Working with a diverse set of institutions is critical for identifying the full range of constraints to microbial water quality testing and all opportunities for achieving optimal testing frequencies and coverage. Our program recruitment will focus on achieving diversity by allocating time for background research on the African water sector and for iterations to the RFPs as necessary to promote broader participation. We will also adapt and refine our payment models based on early feedback.

By combining quantitative and qualitative research methods, we will ensure a nuanced understanding of the dynamics of water quality monitoring. Our robust strategy for data collection and analysis will confirm that we address stated research questions and achieve targeted outcomes and milestones related to developing a thorough understanding of the factors that limit microbial water quality testing across SSA and evidence-based strategies for addressing these constraints.

D. Assumptions and Risks Concerning Implementation and Results

Lack of interest

The central risk to our program is a lack of interest among targeted program participants: municipal water utilities and public health surveillance agencies across SSA. We may find that despite regulatory requirements, microbial water quality testing is not a sector priority and that even when motivated with financial incentives, institutions may prefer to focus their efforts on other activities. In addition, some of our potential program participants may perceive that their current testing levels are sufficient; others may be hesitant to increase testing to avoid exposing water management deficiencies, or because resources for responding to non-compliant results are limited.

Mitigation of this risk will require multiple steps:

1. 'Packaging' and presentation of our test payments program as essential public health research that will bring credit to program participants through their contributions to a greater understanding of microbial water quality testing.
2. Emphasizing the technical and personnel capacity gains for program participants.
3. Promoting our program through respected sector authorities that can serve as intermediaries with local institutions. We will negotiate sub-contracts with key convening agencies (i.e. AfWA, IWA, GWPOA, WHO, UNICEF) in the water supply and public health arenas to cover this role.
4. Securing support from national water sector authorities and regulators, which we will address by traveling to selected countries for in-person meetings.
5. Ensuring 'buy-in' from targeted program participants. Through direct meetings and an early program workshop, we will develop a collaborative process for finalizing program guidelines and administering the RFPs.

6. Anticipating attrition of potential program participants through the RFP and contracting process.

Based on our experience in establishing the Aquatest Early Adopter pilots, we believe that these steps will achieve sufficient program participation. In addition, the Foundation has recommended a motivational reward payment for achieving high levels of program participant. As noted in the section, 'Linking budgets and reward payments to program outcomes' we will evaluate interest as our first major program milestone at month 9. If sector interest in our program is low at this point, we will consider alternative strategies for recruiting participants. If we have not achieved sufficient interest and participation by our second major program milestone on month 12, we will terminate the program.

Lack of cooperation

Historical test data and an understanding of baseline testing levels are obvious requirements for setting program testing targets for participants, and we will have to enforce data sharing as a prerequisite for joining our payments program. Our experience with Aquatest Early Adopter institutions indicates that we are unlikely to face restrictions on water quality data access after program agreements are signed. However, poor management and record keeping often render data difficult to compile and share. Consequently, we will budget Aquaya staff time for onsite baseline data collection and entry with each program participant.

In addition to sharing historical water quality data, we will ask the largest program participants, large city providers, to make their water quality data publically available. A quick survey indicates that many large city providers have some mandate for public data sharing, but implementation is week. To encourage follow-thru in data sharing, we will tie payment bonuses for large city program participants to public data sharing. We will also provide a modest budget for web site upgrades and other forms of data presentation such as filers and newspaper advertisements.

Lack of commitment

With regard to program implementation, it is possible that some participants may not follow-through on their agreed-to program commitments. We have to anticipate some 'non-compliance' and begin the program with greatest possible numbers of participants. In addition, staff in some participating institutions may record and submit results without conducting actual tests. We will monitor purchases of testing products and reagents as independent verifications of testing activity. We will also explore two options for using the features of the cell phone applications for additional oversight; for example a GPS field in the reporting form could capture location data to confirm that technicians are truly on site when submitting data. Similarly, the reporting forms could include a field for taking a photo of the completed test.

Finally, participants may perceive our multi-round payment scheme, in which participants of Round 2 are offered greater funds, as unfair. In order to mitigate the negative effects of such a perception we will coordinate with Round 1 participants to explain that additional funds are only made available when absolutely necessary to enable improved monitoring.

E. Measurement

The Senior Program Manager will maintain responsibility for monitoring overall project progress and for providing quarterly written reports to the Executive Director describing progress against milestones, program risks, and other issues. The Kenya-based Program Manager will track day-to-day activities. We will use Merlin project management software to develop a detailed Program Timeline, to assign resources for specific tasks, and to provide a common reference for all program activities (Appendix 3). Constant communication between US-based and African regional staff, complemented by regular visits to Africa by senior staff, will ensure awareness of project status among all team members.

Key milestones associated with each major phase of the project will ensure steady progress towards successful program completion. Milestones related to relationship building, test payment model development and partner recruitment provide a foundation for program implementation. Subsequent milestones for baseline, longitudinal and end-line data collection will ensure sufficient data for a robust analysis.

Output-based milestones, such as developing collaborations, signing a minimum number of program agreements, and holding workshops, will provide clear progress indicators. Frequent and well-spaced milestones will ensure that problems or delays are identified and addressed early. Similarly, we will identify dependencies between activities so that the consequences of any delays are well understood.

While implementing our test payments program, we will use mobile phone and web-based data reporting systems to monitor testing activity and the influences of our test payment schemes in real-time. We will use in-depth Mid-term meetings with all program participants to determine if the test payments should be modified to encourage more testing.

With input from the project team, the Senior Program Manager will document obstacles that emerge throughout the program implementation and will describe whether and how the obstacles were overcome. In addition, we will log changes made to the initial test payment models as a result of consultation with sector actors. By documenting our process, we will maximize the lessons learned from project implementation. Ultimately we hope these lessons will drive comprehensive strategies for achieving optimal levels of microbial water quality testing across sub-Saharan Africa. As follow-on to this project, we will pursue all options for implementing and evaluating microbial water quality testing interventions - with the Foundation and with other WaSH sector stakeholders.